National Bureau of Standards

TECHNICAL NEWS BULLETIN

VOLUME 33 MARCH 1949 NUMBER 3

Spiral Contractometer Measures Stress in Electrodeposits

The spiral contractometer,[1] a new direct-reading instrument developed by Abner Brenner and Seymour Senderoff of the Bureau's electrodeposition laboratory, offers a convenient and accurate method for measurement of stress in electrodeposits. Compression or tension in a specimen coating deposited on a standard helix is immediately read from a dial as the helix changes curvature in response to forces acting within the plated layer. The device is rugged and self-contained, requires no auxiliary apparatus, and is well adapted to both industrial process control and laboratory research.

In recent years there has been a growing realization of the importance of internal stress in the performance of electrodeposited coatings and in the quality of plated articles. Excessive stress, usually the result of the chemical nature of the plating solution or of impurities in the deposit, may cause peeling, blistering, or cracking of the coating and thus render the base metal more susceptible to corrosion. It may also induce failures due to stress corrosion and usually tends to decrease the fatigue resistance of the plated article.

In general, the various methods that have been devised for determination of stress in electrodeposits have involved measurement of the bending of a plated strip by means of a microscope comparator or some type of special gage. Such methods have either lacked reliability or have been too cumbersome for quality control in commercial production. The National Bureau of Standards therefore initiated the development of a direct-reading instrument based on the twisting of a helix rather than the bending of an uncoiled strip. The result was the spiral contractometer, which because of its higher sensitivity, broader utility, and greater ease of operation, is expected to find extensive application in the investigation and control of electrochemical processes.

Essentially the new instrument consists of a flat metal strip wound in the form of a helix and mechanically connected to the pointer of a dial, on which the rotation of the free end of the spiral with respect to its fixed end is indicated. The helix is connected at its upper fixed end to a negative lead and suspended vertically in a plating solution along with a suitable anode. As it is plated with a sample coating on the outside only, the stress in the deposit causes it to wind more tightly or to unwind, depending on whether the stress is compressive or tensile. A rod running down the axis of the helix is attached to its lower or free end so that rotation of this end due to stress is transmitted to the rod. The rotation of the rod, in turn, is applied to a gear train, which produces a ten-fold magnification in the rotation of the dial pointer. The angular displacement of the rod is read directly from the dial in degrees and converted to units of stress on the basis of the calibration of the helix used.

[1] For further technical details, see A spiral contractometer for measuring stress in electrodeposits, by Abner Brenner and Seymour Senderoff, J. Research NBS **42**, 89 (1949) RP1953; also Proc. 35th Annual Convention Am. Electroplaters' Soc. (1948).

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In making a stress determination, the helix is first cleaned and, when necessary for good adherence of the deposit to be tested, a "strike" plate is applied. After the helix has been dried and weighed, the inner side is brushed with thinned "stop-off" lacquer to prevent plating on this surface. The helix is then dipped in hot alkali and acid baths, or other preplating dips, and rinsed before it is mounted in the contractometer and immersed in the plating solution.

The helix may be allowed to twist as plating progresses, and a record kept of the displacements with time; or twisting may be prevented until the end of the run by clamping the pointer. Both methods give the same results within the experimental error.

At the end of a run, the helix is taken out of the solution, cleaned, and dried, and the lacquer is removed from the inside with acetone. The deposit may then be stripped off as soon as it has been weighed to determine its average thickness. Stress is calculated from the observed deflection of the pointer, the physical constants and dimensions of the helix, and the average thickness of the coating.

A single helix can be used almost indefinitely without appreciable change in its dimensions, elastic moduli, or deflection constants, provided reasonable precautions are taken in handling and storing. Between successive runs only the helix and the clamps that hold it are removed, leaving the rest of the assembly intact. During periods of disuse the instrument need not be completely disassembled except for occasional cleaning. When this is necessary, both dismantling and reassembling can be accomplished in less than 5 minutes.

The helix is made by winding a metal strip of uniform width and thickness on a $\frac{3}{4}$-inch steel rod in such a way as to avoid spaces or overlaps between the coils. The width of the strip is about 0.7 inch; its thickness is usually between 0.01 and 0.03 inch, depending on the rigidity required for the particular application. For deposits under very high stress, thicker strips may be used. When the winding is completed, the ends are anchored to the rod with screws. The helix is then annealed in a vacuum to relieve the stresses due to cold working and thus to prevent uncoiling. After annealing, the rod is mounted in a lathe, and the helix is cut off at the desired length and stretched lengthwise until the coils are separated from each other by a distance of about 0.02 to 0.04 inch. Upon removal of the inside rod, the helix is ready for use.

Internal stress in electrodeposited coatings may now be conveniently and accurately determined by means of the spiral contractometer, a self-contained, direct-reading instrument developed at the Bureau. Compression or tension in a specimen coating deposited on a helix is indicated by the pointer of a dial as the helix changes curvature.

Stress determinations made with the spiral contractometer on nickel deposits are reproducible within ± 10 percent. Values obtained with the device are in good agreement with reported values and with measurements made by procedures based on other principles. The length of strip that may be conveniently used as a helix is four to eight times that usually found in the straight-strip instruments. This gives a greater deflection for a given change in curvature, and this deflection can be magnified to any desired degree by the gear system of the instrument. In addition to the greater sensitivity thus attained, the contractometer is easily calibrated, thus simplifying calculations and eliminating errors due to variations in the physical properties of the helix.

TECHNICAL NEWS BULLETIN

U. S. Department of Commerce
Charles Sawyer, *Secretary*
National Bureau of Standards
E. U. Condon, *Director*

MARCH 1949 Issued Monthly Vol. 33, No. 3

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Subscription price $1.00 a year; single copy, 10 cents. The printing of this publication has been approved by the Director of the Bureau of the Budget, February 14, 1947.

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International Conference on Weights and Measures

The Ninth General Conference on Weights and Measures, held in Paris and Sévres, France, October 12 to 21, 1948, marked the revival of an international organization established by treaty in 1875. This organization has held regular meetings since 1889, with the exception of interruptions due to the two World Wars; the Eighth General Conference met in 1933. The Ninth was originally scheduled for October 1939, but was forestalled by the outbreak of war in September of that year. The Conference in 1948, therefore, had to consider developments that had taken place over a period of 15 years. Of the 33 countries now belonging to the international organization, 28 named delegates to the Ninth Conference, totaling 55 in number. The United States delegates, appointed by the Department of State, were Dr. Edward U. Condon, Director of the National Bureau of Standards, and Dr. E. C. Crittenden, Associate Director.

The International Bureau of Weights and Measures, located at Sévres, serves both as a laboratory and a secretariat for the General Conference and for the permanent International Committee on Weights and Measures. Although working under difficult conditions, that Bureau was able to continue its work throughout all of the war period. Its buildings suffered some damage from aerial bombardment, but the international "prototype" standards of length and mass, the International Meter and the International Kilogram, were not damaged, since they were stored in well-protected subterranean chambers.

Among the functions of the International Bureau is the periodic comparison of national standards with the international prototypes preserved at Sévres. At the Ninth General Conference the Bureau reported measurements on a few national meters, completing the first periodic intercomparison, and on a considerable number of national kilograms. With the exception of two kilograms, which were known to have been used a great deal, no one of the national standards supplied for comparison showed changes from its original value greater than the possible errors of measurement. For example, among the standards compared was the Kilogram No. 20, which constitutes the basic standard of mass (or "weight") of the United States. This Kilogram was previously compared with the international standard in 1937. The results obtained in 1948 differed from those found in 1937 by only two parts in a thousand million. These recent values differ by two parts in a hundred million from the value of the standard certified in 1889; however, the weighings at that time were not sufficiently precise to make it sure that any real change in the standard has occurred.

In spite of the excellent performance of the platinum-iridium meter bars during the 60 years since they were distributed, the search for a less arbitrary standard of length has gone on. In particular it has been expected that eventually the wavelength of some spectral line might be used as such a standard. Reports made to the General Conference indicated very definite progress in this direction. The production of several substances that consist of a single isotope of an element rather than a mixture of several isotopes has made it possible to obtain lines of simple structure that give sharp patterns in the optical instruments by which measurements are made. One of the most promising of these is the green line of mercury 198, an artificial isotope transmuted from gold by neutron bombardment.[2] Although not specifically mentioning mercury 198, the General Conference formally recognized the fact that spectral lines of this type combine in the highest degree the qualities required to constitute satisfactory standards of length. It requested the national laboratories and the International Bureau to continue the study of such lines with the expectation of eventually establishing a new definition of the meter based upon the wavelength of a particular line emitted under specified conditions.

In the field of electrical measurements there was reported to the Conference the consummation of the plan approved by the Eighth Conference in 1933 to redefine the units so as to make them concordant with the basic mechanical units of length, mass, and time. The revised values of electrical units were in fact introduced into use as of January 1, 1948, in accordance with action taken by the International Committee on Weights and Measures.[3] At the same time a new system of photometric units was introduced replacing the two diverse systems that had been in use previous to that date. The Ninth General Conference confirmed both of these actions.

The most important new technical development dealt with by the Conference was the adoption of a revised text describing the International Temperature Scale (see page 28, this issue). As a result of discussion of the two terms "centigrade" and "centésimal", which have been applied to the Temperature Scale used in metric countries and in scientific work elsewhere, the Conference recommended adoption of the name "Celsius" in preference to either of the other terms.

The International Temperature Scale is a practical realization of the theoretical thermodynamic scale, which has commonly been defined by reference to two fixed points—the freezing point and the boiling point of water. Following a proposal of the International Union of Physics, the Conference recognized the possibility of defining an absolute thermodynamic scale of temperature by fixing a single fundamental point, for which the triple point of water would now be taken. However, to make the scale so defined agree with the Kelvin scale now in use, it would be necessary to determine precisely the numerical value for that fixed point, and on this numerical value the Conference could not agree, opinion being divided between 273.16° and 273.17°.

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[2] Light wave of mercury 198 as ultimate standard of length, NBS Technical News Bulletin **31**, 133 (Dec. 1947).

[3] NBS Circular C459, Announcement of changes in electrical and photometric units. Available from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at 5 cents a copy.

Another point on which there was much discussion was definition of units of heat. The joule was unanimously recommended as a preferred unit, but some workers continue the use of a calorie, and it has not been possible to reach agreement on the definition of any single unit bearing this name. The Conference, therefore, recommended that workers using the calorie should furnish all the information necessary to convert their results to joules.

From various sources the Conference received recommendations for the establishment of a general international system of practical units. (These recommendations of course referred to metric units, since the international organization does not attempt to deal with the Anglo-Saxon system of units.) The French national office of weights and measures presented detailed proposals regarding such a general system. The Conference instructed the International Committee to conduct a survey of opinions in scientific, technical, and pedagogical circles of all countries in the hope of establishing a single system of units. Inquiries to this end will be transmitted through official governmental agencies.

Various other technical questions were considered by the Conference. One of these which may be of general interest was the naming of large numbers. In many countries names ending in -illion are applied to digits in groups of six, whereas in other countries, including the United States, such names are applied to groups of three digits. In the hope of reconciling this difference the Conference favored the former practice; but, since the United States representatives could not agree to such a recommendation, the resolution adopted proposed the introduction of that particular system in European countries.

In addition to the technical problems mentioned, the Conference had also to deal with various administrative matters affecting the International Bureau. For example, a new scale of contributions to be paid by the various member-countries was established, and it was agreed that the basic contribution to the International Bureau should be raised from 150,000 gold francs ($49,005) to 175,000 gold francs ($57,172.50) as soon as the major countries (Japan and Germany) that are not now able to pay their dues resume payments.

New International Temperature Scale

On January 1, 1949, the National Bureau of Standards began using the definitions of the International Temperature Scale of 1948, both in its own research program and in calibrating instruments for other scientific and industrial purposes. Derived from a draft prepared by members of the Bureau staff, the new scale was adopted at Paris by the Ninth General Conference on Weights and Measures in October 1948, and the official text was approved for publication before the end of the year. This is the first revision of the International Temperature Scale since its adoption 21 years ago. The experimental procedures by which the scale is to be realized are substantially unchanged; but certain refinements, based upon experience, have been incorporated to make the scale more uniform and reproducible.

The experimental difficulties inherent in the measurement of temperature on the thermodynamic scale (an ideal scale based on energy changes in a Carnot cycle) led to the establishment in 1927 of the practical scale known as the International Temperature Scale. This scale is based upon six reproducible equilibrium temperatures, or "fixed points", to which numerical values are assigned, and upon specified interpolation formulas relating temperature to the indications of specified standard temperature-measuring instruments. The scale is designed to conform, as nearly as practicable, to the thermodynamic Celsius [4] scale, as it is now known. At the present time, however, it is possible to obtain values of temperature on the International Temperature Scale more accurately than on any thermodynamic scale.

The International Temperature Scale of 1927 proved useful in providing a stable, uniform, and precise basis for obtaining temperatures. However, since its adoption, the increasing precision attained in temperature measurements had made it apparent that some revision was desirable in order that measurements of physical constants—for example, the freezing and boiling points of pure compounds—might be made on a more exactly comparable basis by laboratories in all parts of the world. Because of the present leadership of the United States in the fields of heat and thermometry, the major responsibility for proposing and obtaining agreement on the changes fell to the National Bureau of Standards. After many consultations with scientists and laboratories in this country and abroad, the Bureau prepared a draft that formed the basis of the document finally adopted by the General Conference as the International Temperature Scale of 1948.

The six fixed points of the 1927 scale were the boiling point of oxygen (−182.97° C), the freezing and boiling points of water, the boiling point of sulfur (+444.60° C), the melting point of silver (+960.5° C), and the melting point of gold (+1,063° C). From −190° to +660° C, the measure of temperature was based on the indications of a standard platinum-resistance thermometer used in accordance with specified formulas. From +660° C to the gold point, a platinum-platinum rhodium thermocouple was the reference instrument; and above the gold point, the optical pyrometer has been standard.

The same fixed points, with one slight modification, are specified in the 1948 scale, and the laboratory procedures for obtaining temperatures between fixed points are essentially the same as those previously used. Only

[4] The Ninth General Conference decided to abandon the designation "Centigrade" and use "Celsius" instead.

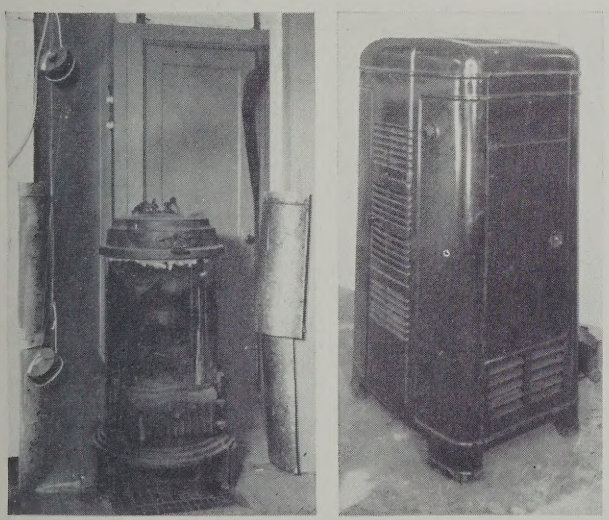
two revisions in the definition of the scale result in appreciable changes in the numerical values assigned to measured temperatures. One of these is the change in the value for the silver point from 960.5° to 960.8° C, which affects temperatures measured with the standard thermocouple. Thus, in the range between 630° and 1,063° C, numerical values of temperature are higher than on the 1927 scale, the maximum difference being about 0.4 degree near 800° C. The adoption of a new value [5] (1.438 cm-deg) for the constant c_2 in the radiation formulas changes all temperatures above the gold point. In the new scale, Planck's radiation formula is specified instead of Wien's for calculating temperatures above the gold point as observed with an optical pyrometer. Since Planck's law is consistent with the thermodynamic scale even at high temperatures, this change removes the upper limit to the scale formerly imposed by the use of Wien's law.

There are several other important modifications in the scale that cause little or no change in numerical values for temperatures but serve to make the temperatures more definite and reproducible. For example, the standard platinum-resistance thermometer is to be used as a reference instrument from the oxygen point to the freezing point of antimony (about 630° C), rather than over the range from −190° to +660° C. Platinum of higher purity is also specified for the standard resistance thermometer and standard thermocouple, and smaller permissible limits are given for the electromotive force of the standard thermocouple at the gold point.

[5] NBS Technical News Bulletin **32**, 2 (Jan. 1948.)

Performance of Space Heaters in a Test Bungalow

Radiant and jacketed space heaters [6] are widely used in small houses in both Federal and other housing projects. Because of the dearth of data concerning the heating characteristics of this type of heating device, an investigation of the performance of space heaters has been completed by the Building Technology Division of the National Bureau of Standards. The Bureau's tests were conducted in a four-room Test Bungalow completely enclosed by an insulated outer shell so that the temperature might be varied to simulate any condition throughout the United States. This bungalow has been in use for a number of years at the Bureau for research in heat transfer phenomena in small houses. Objectives of the present studies [7] were a comparison of the temperatures produced by radiant and jacketed heaters in different positions; a comparison of effects of different heater jackets; recommendations regarding the limitations of space-heater use; and a determination of whether or not unattached fans, transoms over interior connecting doorways, and underfloor plenums improve conditions in a home heated by a space heater.



Various types of space heaters were used in the Bureau's investigation of their performance in small homes. Experimental arrangements included placement of heater over a return floor register (left) and different means for circulating heated air, for example, the small blower (right rear).

Space heaters are more widely used for house heating in the United States than any other single type of heating equipment. According to the Housing Census of the Bureau of Census for 1940, 35 percent of all urban homes and 63 percent of all rural homes were heated by space heaters of one kind or another. Such heaters are manufactured for burning the common types of fuel such as wood, coal, oil, or gas. Factors responsible for their widespread use include low first cost, efficiency, ease of installation, low fuel consumption, and provision of a zone of comfort by radiation near the heater. The first cost of a space heater is much less than that of a central heating plant, and for efficiency of fuel utilization many space heaters compare favorably with central heating plants; they also have a great advantage over open fireplaces. These considerations tend to justify claims made by the manufacturers that space heaters furnish the cheapest heat in the world and are responsible, at least in part, for the predominant use of space heaters in small houses.

One of the principal disadvantages of space heaters—other than those using oil or gas—is the inconvenience of bringing in fuel and removing ashes, since both operations create dust. Other disadvantages are the loss of usable space in the living quarters and the lack of "even heat" or uniform temperatures throughout the house. For these reasons, other home-heating methods, such as steam, warm-air, or hot-water systems, are sometimes preferred.

[6] For technical purposes a space heater has been defined as an "above-the-floor device for the direct heating of the space in which the device is located without the use of external pipes or ducts as integral parts of such heating device". (See Flue-connected oil-burning space heaters, NBS Commercial Standard CS101-43). Space heaters have long been known as heating stoves in this country, to distinguish them from cooking stoves.

[7] For further technical details, see Temperature distribution in a test bungalow with some radiant and jacketed space heaters, NBS Building Materials and Structures Report BMS114. Available only from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at 25 cents copy.

For test purposes, heat was supplied to the space heaters by means of a cylindrical electric-heating element fitted into the combustion chamber. Better control of the heater and more accurate measurement of the energy supplied were obtained through this procedure.

The Test Bungalow at the Bureau is similar to House B, described in FHA Technical Bulletin No. 4, "Principles of Planning Small Houses." It has four rooms and a bath on one floor with a small hallway near the middle of the structure. Various arrangements of the interior partitions and doors are possible; two different arrangements were used during the space-heater tests. The outside walls of the bungalow are conventional in construction and consist of 2- by 4-inch studding with sheathing and lap siding on the outside, separated by a layer of building paper, and ½-inch gypsum board on the inside. The walls are not insulated nor are the windows and doors weather-stripped. The bungalow has a double floor; both subfloor and finish floor are of 1-inch pine with building paper laid between in the conventional manner. The ceiling, which is insulated with 3⅝-inch rock wool batts, consists of ¼-inch plywood supported by a framework of 2- by 4-inch timbers. The windows, of wooden frames and sashes, are double hung, with the exception of those in the bathroom and kitchen.

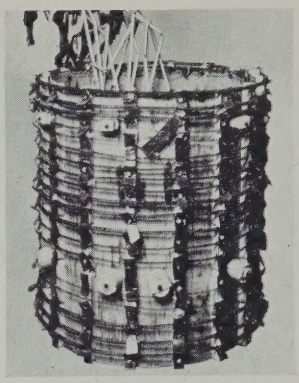
Two coal-fired radiant space heaters of the magazine type were chosen for the Bureau's temperature distribution tests. Designated as heaters A and B, these were of the following size and capacity.

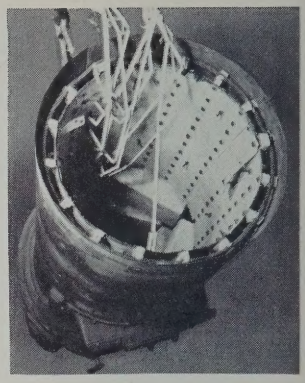
Heater	Nominal coal capacity	Grate area	Body diameter	Over-all height
	lb	*sq in.*	*in.*	*in.*
A	100	177	19	42
B	200	227	21	50

The third specimen, heater C, was a coal heater of the surface-fired type with a cast-iron jacket. Data were also obtained on commercial models of a gas-fired and an oil-fired space heater.

Heater A was fitted successively with four sheet-metal jackets spaced at different distances from the heating surface. Each jacket was cylindrical in shape, conforming to the body of the heater, and extended from the level of the ash pit to that of the lower edge of the dome section. The jackets were spaced at the following distances from the heating surface: Jacket 1, 2½ inches; 2, 4 inches; 3, 6 inches; and 4, 4 inches with an inner liner spaced 1 inch from the jacket.

For test purposes, the smoke pipes and firebrick linings were removed from heaters A and B. Heat was supplied to each by means of a cylindrical, electric-heating element fitted into the combustion chamber, thus permitting better control of the heater and more accurate measurement of the energy supplied. The electric-heating element consisted of nichrome wire coils wound in horizontal turns around a 16-inch cylinder





that was separated from the fire-box wall by a 1-inch air space. The heat output—equal to the electric energy input—was measured with calibrated watt-hour meters graduated in divisions of 10 watt-hours. By placing the jacketed cast-iron heater C on a platform scale and firing with anthracite, fuel consumption was determined very closely by the decrease in weight during test. Flue-gas losses were determined from flue-gas temperature and analysis.

Temperatures in the bungalow during the tests were measured by means of thermocouples covered with cork insulation and supported at five different elevations above the floor, namely, 2, 30, 60, 78, and 94 inches. Five such sets of thermocouples were used in each of the four large rooms, one at the center of the room and one midway between the center and each corner. In the living room the center string of thermocouples, being too near the heater, was moved toward the double window to a position 36 inches from the wall. Three strings were used in the bathroom, one at the center of the room and one midway between the center and each of the walls along the longer axis of the room.

Heater A with each of the four jackets, heater B, and heater C were investigated in one or more of four positions: (1) At the intersection of the center lines of the fireplace and of the doorway between the living room and south bedroom; (2) on the center line of the fireplace and with the stove 30 inches from the north wall of the living room; (3) on the center line of the doorway between the living room and south bedroom and with the stove 28 inches from the east wall of the living room; and (4) in a central location provided by cutting a temporary opening in the living room partition on the north side adjacent to the hallway.

All heaters were tested with natural circulation of the air over the heating surface and in the living space. In addition some tests were made with all except heater B by using a 12-inch, four-bladed fan in the vicinity of the heaters to force the warmed air toward adjoining rooms. Best results were obtained with the fan located on the fireplace mantel forcing warm air toward the hall.

It often happens that one room is too warm for comfort in the "living zone" (that is, the space between 2 and 60 inches above the floor), whereas another room is too cold at some level. For these tests, therefore, the total temperature difference in the living zone is defined

as the difference between the average temperature at the 60-inch level in the living room and the minimum average temperature at the 2-inch level in any room. This follows because the living room is always the warmest room. The total temperature difference reflects the ability of a heater to produce uniformity of temperature both vertically and horizontally in the entire house.

Based on the reactions of the personnel used as observers during these tests, a temperature of not less than 60° F at 2 inches above the floor, and a temperature of not more than 85° F at 60 inches above the floor were considered as providing minimum acceptable comfort. The average radius of the area around each space heater that complied with these temperature requirements was determined for all tests. This radius ranged from 7 feet when the outside temperature was 0° F, to 35 feet for an outside temperature of 50° F.

The investigation has established several general conclusions. The maximum total temperature differences produced in the living zone of a house by a space heater are almost directly proportional to the heat output. Furthermore the radius of the comfort zone decreases as the outside temperature decreases. Although the conditions for acceptable comfort as here defined are based on the reactions of only a few persons, the data indicate the temperatures and the radii of the zones of comfort likely to occur when houses similar to the test bungalow (in size, construction, and degree of insulation) are warmed by space heaters.

Houses with insulation in the walls or with storm windows and weatherstripping would have a lower heat loss per unit area than the test bungalow and could, therefore, be warmed at a lower outside temperature without exceeding a given temperature difference in the living zone. Structures larger than the test bungalow could be warmed by a space heater for moderate outside temperatures. In producing temperature distributions approaching uniformity among the several rooms of the test bungalow, the devices tested fall into the following order of decreasing merit: (1) Jacketed heater at approximate center of house; (2) radiant heater at approximate center of house; (3) jacketed heater in living room; (4) radiant heater in living room.

Bureau tests in general show that a radiant heater, in any of the four positions described, produces slightly lower temperature differences between the 2- and 60-inch levels than a jacketed heater, and when located near the center of the house, produces a given temperature condition in the living zone with 15 to 20 percent less heat output than a jacketed heater. A double-walled heater jacket is more effective than any of the single jackets in reducing the temperature difference between rooms in the Test Bungalow. For single jackets, the width of the air space does not materially affect the temperature distribution for widths from 2½ to 6 inches.

In addition, the variation in size and height of space heaters used for heating residences has a slight effect on the temperature in the room containing the heater but no significant effect on the temperatures in other rooms of the house. The use of open transoms over doorways connecting adjacent rooms augments the flow of heat to the colder room, although the effect becomes increasingly less at the lower levels in the colder room.

It was also shown that the heat distribution in the house could be improved by the use of a desk fan placed to receive warmed air from the heater and blow it toward the door or an opening to another room. This effect varies with such factors as the size and power of the fan and its proximity to the heater. In fact, results of earlier space heater tests using integral fans have indicated that the unattached fan is as effective as the integral fan in improving the distribution of heat.

Building Codes and Construction in the United States

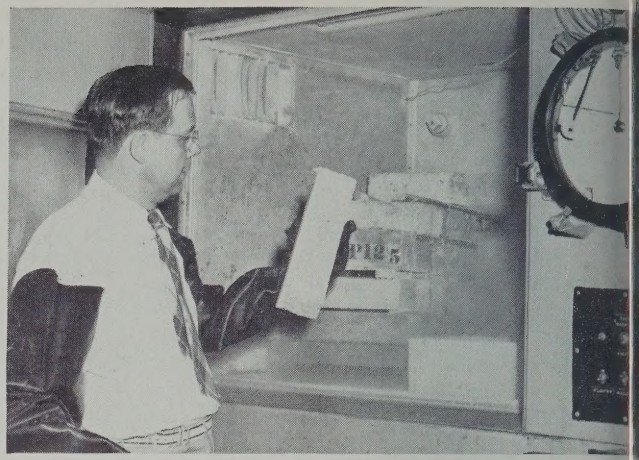
The housing shortage in the United States has focused attention on two problems relating to building codes: First, the present status of building codes and, second, the relation of existing codes to the rate of construction. There have been many discussions of these two problems in recent years, but data have not been available as to the actual status of the codes themselves. Furthermore, the problem of codes and their relation to housing has been over-simplified.

The present status of building codes has been studied by the Building Technology Division of the National Bureau of Standards. Analysis of the data reveals that most of the codes have not been overhauled for some time; a considerable fraction of municipalities in the United States have no type of building regulation; and over 200 municipalities are completely revising their codes, indicating appreciation of engineering advances in the field of building construction.

These facts are significant. The average age of present codes suggests the need for revision, and the number of revisions under way shows recognition of this need. At the same time, it is apparent that codes are needed in those areas that lack building regulations, because the existence of building codes stems directly from the concern of state and local governments for the public safety. Fire, collapse, and unsafe conditions in buildings account for considerable loss of life and many personal injuries. It is in the effort to prevent these events that municipalities establish requirements providing a reasonable degree of fire resistance and strength.

Status of Building Codes

The Building Technology Division of the Bureau maintains an index of municipalities with populations



Research and investigations at the National Bureau cover the entire field of building technology, rang structures like bridges and dams. Data relating to For example, (left to right) fire-resistance ratings, of building elements such as floors. These data in electrica

of 2,500 and over, records the dates of local building codes in effect, and compiles other data concerning building regulations. Sources of material are civic journals, trade and technical publications, engineering and architectural magazines, correspondence with local officials, and an extensive library of codes that now numbers 1,358 items. Recently, a survey was undertaken to provide a check on the information at hand and to furnish more complete coverage. Inquiries were sent to 3,640 municipalities, and 2,634 replies were received. These, together with the data already available, form the basis of this summary of the number of building codes in effect, the age of such codes, and the amount of revision going on.

The facts disclosed by the survey confirm the general impression that a considerable number of codes have not had a major overhauling for some time. When arranged according to the dates attributed to them by local authorities, codes now in effect can be classified into the six groups presented in table 1.

TABLE 1. *Age of dated code*

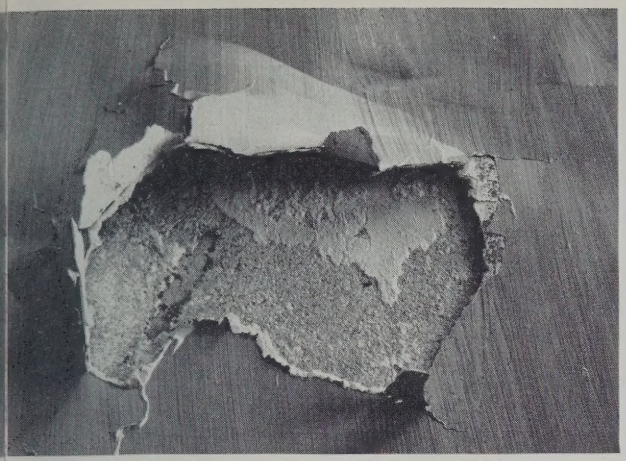
Age group	Number of cities	Percentage
Up to 5 years	574	27
6 to 10 years	366	17
11 to 15 years	244	11
16 to 20 years	377	18
21 to 25 years	327	15
Over 25 years	264	12
Total	2,152	100

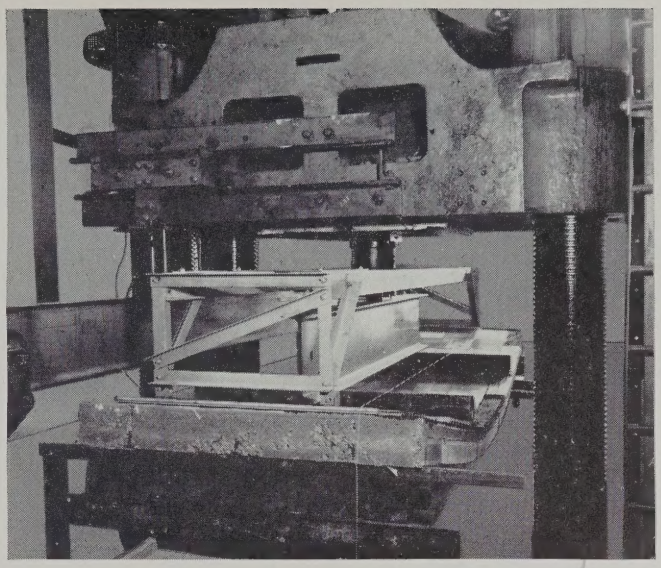
The data on age of codes may be subject to some error, first, because there is uncertainty as to some dates and, second, because amendments in some cases have the effect of modernizing a code without leading to a change of date. These factors, however, are not sufficiently significant to affect the summaries in any appreciable way.

The dates accepted were those furnished by the enforcing authorities, but some difference of interpretation is possible. Thus, a code may be assigned a date as of the time it was officially adopted and yet be more modern than this date would indicate because of amendments. On the other hand, a code of rather ancient vintage may often be reissued with a recent date on its cover, perhaps indicating a deliberate reaffirmation of the old requirements but more probably representing merely a reprinting without critical reexamination. Such cases are known to exist. To some extent they offset each other, but in view of the known tendency to pass frequent amendments it is probable that the cases of partial modernization are more frequent.

The fact that amendments have been added does not necessarily mean that the codes have been actually brought up to date. First, most amendments tend to be minor. Second, even major amendments usually do not achieve the results attainable by complete and total revision. Third, designers and builders are faced with difficult problems in determining what is actually required in a code where numerous amendments have been superimposed on it, and the attendant confusion and uncertainty help to minimize the beneficial effect of such amendments.

It is significant that 29 percent of the municipalities have no type of building regulation. Some municipalities do not have codes but do have rudimentary ordinances requiring permits in order to do building, or setting geographical limits within which some types of combustible construction may not be erected. Others make use of state regulations. Information of this kind is summarized in table 2.





rds, extending over a period of nearly 50 years, mall dwelling units and their components to large f structural materials are compiled and integrated: l thawing of concrete, plaster failures, and strength pplied in the development of building, plumbing, r codes.

TABLE 2. *Data on municipalities without codes or dated codes*

Code information	Number of municipalities
No code	990
Permit ordinance	183
Fire limits ordinance	164
State regulations adopted	37
No code age given	47
No report on code status	67

The absence of codes in such municipalities suggests that in these areas new materials, construction methods, and designs may be used. To a limited extent this is true, and some of these regions have served as proving grounds for new developments. On the other hand, the absence of codes represents a real hazard to the public safety and often to the economic interest of property owners.

The data for the entire country are of considerable interest. They show that 71 percent of municipalities have some sort of regulation. Building codes are, however, essentially an exercise of state authority. The actual requirements are generally local in character by virtue of a delegation of the state power to municipalities through charter provisions or enabling acts, but the power itself is of state origin. Hence it is of interest to see how generally this power has been exercised within each state (see table 3).

Table 3 indicates that in certain states (Nevada and Washington) all municipalities of 2,500 population or over have some form of building regulation; in others, such as California, practically all are covered; in still others, such as Mississippi, the coverage drops well below half.

Here again some qualification is necessary, for many states have miscellaneous legislation applying to certain buildings throughout the state, and others have state building codes. The figures for Wisconsin indi-

TABLE 3. *Summary of municipal building codes by States*

State	Dated codes	Other regulations	Total regulated	No code or no report	Total
Alabama	36	3	39	20	59
Arizona	12	3	15	1	16
Arkansas	19	12	31	22	53
California	163	2	165	2	167
Colorado	26	1	27	3	30
Connecticut	39	9	48	31	79
Delaware	5	1	6	2	8
District of Columbia	1		1		1
Florida	53	9	62	7	69
Georgia	46	12	58	19	77
Idaho	18		18	8	26
Illinois	109	13	122	86	208
Indiana	37	16	53	44	97
Iowa	38	15	53	36	89
Kansas	46	9	55	9	64
Kentucky	24	6	30	26	56
Louisiana	23	8	31	23	54
Maine	20	7	27	13	40
Maryland	12	2	14	8	22
Massachusetts	106	6	112	72	184
Michigan	79	17	96	29	125
Minnesota	36	25	61	17	78
Mississippi	16	6	22	26	48
Missouri	47	12	59	28	87
Montana	17	3	20	3	23
Nebraska	19	6	25	11	36
Nevada	5		5		5
New Hampshire	11	1	12	21	33
New Jersey	182	3	185	19	204
New Mexico	17	2	19	2	21
New York	150	6	156	51	207
North Carolina	35	40	75	1	76
North Dakota	11		11	1	12
Ohio	81	19	100	86	186
Oklahoma	48	8	56	18	74
Oregon	28	3	31	3	34
Pennsylvania	137	58	195	161	356
Rhode Island	23		23	6	29
South Carolina	29	11	40	10	50
South Dakota	14	1	15	4	19
Tennessee	35	9	44	14	58
Texas	111	32	143	53	196
Utah	21	2	23	3	26
Vermont	4	2	6	9	15
Virginia	38	4	42	11	53
Washington	37	3	40		40
West Virginia	23	6	29	16	45
Wisconsin	55	17	72	21	93
Wyoming	10	1	11	1	12
Total	2,152	431	2,583	1,057	3,640

cate that only 60 percent of the municipalities have codes, but there is a state building code in effect covering all but one- and two-family dwellings. Thus, the fact that a municipality does not have a code does not necessarily mean that it is altogether without building regulation, although in many cases this is so, as shown in table 2.

Response to the question whether revision was going on or contemplated provides an indication of the concern of local governments about bringing the codes up-to-date. The replies are summarized in table 4.

TABLE 4. *Prospective code changes*

Kind	Number of cities
Revising	213
Planning revision	32
Drafting code	50
Contemplating code	9

One of the difficulties that city councils have to deal with in revising their building codes is the necessity for publication of the document in local newspapers. The cost of publication is a deterring influence when the question of revision comes before these councils. Probably for this reason more than for any other, city councils use the procedure of amendment from time to time when they find need for making specific changes in their codes. More basic than this, however, is the role of caution, in keeping with the primary function of codes—public safety. Even in those areas where codes are in existence, fires, structural failures, and other unsafe conditions account for a considerable number of deaths, injuries, and property losses annually.

The status of present building codes requires careful consideration in view of the disparity in age, type, and scope of regulations and various local factors. Any analysis that is to escape oversimplification must consider not only the fact that most codes are, in varying ways, out of date but that nearly one-third of the municipalities lack proper regulations and that some codes are not rigorous enough, raising the question of the public safety. Revision of old codes is complicated by at least two factors: (1) Testing and evaluation problems involved in the appraisal of new materials and developments for revision of codes are many and complex, and exceed the facilities of municipalities. (2) Diversity of geographic and climatic conditions necessarily requires variations in the detailed regulations of codes. However, greater uniformity in codes is feasible, and such uniformity would achieve economies in construction and simplify the problems of designers, builders, and manufacturers.

Codes and New Construction

The statement is frequently made that existing building codes tend to become out of date through failure to keep abreast of engineering developments. The above statistics corroborate this view, and the fact that over 200 municipalities are actively engaged in complete revision of their codes indicates the growing appreciation of the benefits to be derived from modern codes.

Any appraisal of the effect of building codes on present rates of construction must take into account several factors, each complex. Building costs without question represent the most important limitation on rate of construction. Codes affect costs and thus construction where they unduly restrict the utilization of more economical materials, methods, and design. There have been advances in science and engineering that are not now adequately reflected in many building codes, and here modernization of codes is important. However, the influence of codes on rate of construction is secondary to that of the cost of materials and labor.

Delays in code revision are partly due to lack of standard methods of testing and of evaluating new developments in materials, methods, and design. Local authorities engaged in building-code revision have a number of sources of information to which they can turn: Organizations of building officials, fire underwriters' associations, and standardization bodies, as well as the National Bureau of Standards and other Government agencies. The dissemination of technical information by such organizations represents an important element contributing to the application of new developments in the construction field and to the maintenance of proper safety measures.

Thus, the National Bureau of Standards has placed its findings at the disposal not only of Federal agencies but also state and local governments, which are primarily concerned with building regulations. The investigations of the Bureau, extending over a period of nearly 50 years, cover the entire field of building technology, ranging from small dwelling units to large structures like bridges, dams, and skyscrapers. Data relating to properties of materials, whether acquired as a part of the building technology program or in the other programs of the Bureau, are compiled and integrated for this purpose. The importance of such synthesis stems from the fact that thousands of materials and products are utilized in construction.

Results of fundamental research; development of test methods; testing and evaluation programs; the establishment of voluntary commodity standards; and the development of building, plumbing, electrical, and safety codes (in cooperation with other Federal agencies, state and local governments, industry, and labor) are made available by the Bureau. This is accomplished through publications and reports; by consultation and correspondence; and through committees in the engineering, architectural, industrial, and governmental fields associated with building codes and construction.

Research, Codes, and Construction

There is some danger that the effect of codes on the current rate of construction may be overemphasized, and this danger is a very real one in a period

in which the housing shortage is acute. It would be unfortunate to make a whipping boy of codes, for though codes are a factor they are by no means the only or the most compelling one.

The cost of housing is determined above all by the cost of materials and labor, but another element enters even into this situation. It is not merely that material costs and labor costs have risen during the war and postwar periods, but also—and this is just as important if not more so—that American concepts of what constitutes adequate housing have changed. These concepts have changed in the direction of demanding, directly or indirectly, more expensive housing.

The phenomenon is perhaps seen more clearly in a comparison of housing in the early years of the century and in the present period. Some 30 or 40 years ago, small dwelling units were considered adequate if they provided a fair amount of living space. Heating was obtained through inexpensive stoves. Lighting was provided frequently by kerosene lamps; in urban areas where electricity was available, wiring was elementary. Plumbing was simple; in rural areas it was often scarcely in evidence.

Now, however, an acceptable dwelling unit is expected to have central heating, extensive plumbing with bathrooms and kitchens that are not only functional but aesthetically pleasing, and electrical installations having many outlets and capable of handling the rather heavy loads that modern appliances require (ranging from lamps, toasters, and fans to ranges, refrigerators, radios, and washing machines). Considerations of comfort emphasize the desirability of thermal insulation. These changes in our concepts of suitable housing are also responsible for some of the increased costs of construction.

The role of research in this picture is two-fold: In many cases research contributes to lower costs; on the other hand, research developments, through the variety of materials and methods so produced, increase the number of problems faced by building-code officials. Where a large variety of new materials and methods is involved, as now, the magnitude of the testing and evaluation problems is formidable. For this reason the Bureau has not only pursued a vigorous program of research, but of testing and of developing methods of evaluation as well. The results of these investigations have been put at the disposal of all bodies interested in construction.

One of the factors apt to be slighted in considering housing research is the inter-relationship of such research with research in the whole construction field and in fields apparently completely divorced from housing. The reason for this lies again in the variety of products and materials used in construction. Any concept of housing research that does not take cognizance of the entire construction field and of research in almost every subfield of physics, chemistry, engineering, and even mathematics is doomed, in all probabilities, to failure if for no other reason than that the pertinent developments in these fields will be overlooked.

The validity of this observation has been confirmed in the experience of the Bureau. For years the investigations of approximately one hundred sections of the Bureau in physics, chemistry, engineering, and mathematics—exclusive of those directly concerned with building technology—have produced valuable results which were desired initially for purposes other than construction but which were invaluable in the building technology program. At the same time, the fact that the Building Technology Division was concerned with the whole field of construction provided data of great basic importance to housing. For example, as a result of studying the problems of design and engineering in large structures, such as bridges, steel ships, and skyscrapers, the Building Technology Division was able to apply engineering principles to the design of small dwelling units. The art of construction of small houses has been largely empirical. The new approach, made possible only by the research and experience in the broader field, has vast economic implications with respect to housing construction. The book in which the Bureau's investigations are presented, Strength of Houses,* is destined to be a classic in its field.

Further and more extensive work in all of these fields—research, test methods, testing and evaluation, modernization of codes—is clearly needed. Such work is needed not only because the problems are many and diverse, but because the entire subject of construction is closely interwoven with the future development of our economy, and the causes of present shortages lie not only in the last few years but in the last 2 to 3 decades.

Thus, the housing shortage is more than a postwar phenomenon; it has actually been growing during the last quarter century. The depression years accounted for a marked decline in housing construction; shortly after that, the war prevented the allocation of materials and manpower for this purpose. Moreover, during the last 20 years the population of the United States increased by approximately 28 millions, or more than 23 percent. At the same time, those factors that limited new construction acted as deterrents to repair and maintenance. The total effect of these factors means that today the housing shortage is perhaps even more critical than is commonly known. This, in turn, emphasizes again the need for additional research, development, testing, and evaluation as well as the revision of codes.

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*Strength of Houses, National Bureau of Standards Building Materials and Structures Report 109 (available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., $1.50 per copy).

Conference on High-Frequency Measurements

A conference on high-frequency measurements, sponsored jointly by the American Institute of Electrical Engineers, the Institute of Radio Engineers, and the National Bureau of Standards, was held in Washington, D. C. on January 10, 11, and 12, 1949. This was the first conference on a national basis to be devoted solely to high-frequency measurements and instrumentation, a field that is rapidly attaining greater importance in science. The technical program, consisting of four sessions over a 3-day period, included surveys of various branches of the art, and presented the latest developments in measuring techniques.

The first session on frequency measurements covered frequency stabilization by means of spectrum lines. The Bureau's atomic clock (NBS Technical News Bulletin, Feb. 1949) and atomic oscillators, and recent work on klystron oscillators stabilized by absorption lines of ammonia, as carried out at the RCA Laboratories and at Harvard by servo methods, brought out the great importance of microwave spectroscopy to radio technique. Included in the session were papers on superconducting resonant cavities and measurement of frequency in the millimeter bands.

The second session on power and attenuation measurement techniques discussed power sources for measurements work, new broad-band bolometers, metallized glass attenuators, and a power splitting unit at X-band, which does not shift the phase of the input signal. A figure of merit for directional couplers was also proposed.

The subject of impedance and dielectric measurement was treated in session three. Impedance meters, which are still undergoing rapid development, were discussed in two papers, including one in which a direct-reading, null-type instrument was described. Dielectric measurement techniques in the UHF range were reviewed by the Laboratory for Insulation Research of the Massachusetts Institute of Technology. The final session on noise and antennas included reviews of a new program of antenna instrumentation, microwave noise sources, and measurement methods for artificial dielectrics such as used in microwave relay antennas.

Fire Resistance of Structural Clay Tile Partitions

Complete data on the performance of 20 structural clay tile partitions subjected to fire-endurance and hose-stream tests at the National Bureau of Standards are contained in a new Building Materials and Structures Report, BMS113, *Fire Resistance of Structural Clay Tile Partitions.* For over 30 years the Bureau has been actively engaged in research on fire-prevention and fire-protection problems. In view of the lack of information on the fire-resistance properties of nonbearing structural clay tile partitions, a series of tests of such partitions has recently been carried out as part of the Bureau's program of research in the field of building technology.

Twenty partitions, constructed of representative commercial materials in three different thicknesses (3, 4, or 6 inches), were subjected to standardized fire-endurance and hose-stream tests in the Bureau's wall-testing furnace. Five were not plastered, three were plastered on one side, and the others were plastered on both sides. Most of the partitions had one cell through the thickness, although a few had two rows of cells. The tiles were obtained from three of the principal clay tile manufacturing districts of the United States.

The eight chapters of the report describe the materials and construction of the partitions as well as the equipment and test methods used. A full log of the tests and a discussion of results are also included. Building Materials and Structures Report BMS113, *Fire Resistance of Structural Clay Tile Partitions,* is available only from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at 15 cents a copy.

Impregnation of Leather With Synthetic Resins

Resin treatments that promise to improve effectively the wear resistance of sole leather have recently been developed by Rene Oehler and Timothy J. Kilduff of the Bureau's leather laboratory.[8] In addition to increasing the abrasion resistance, the use of synthetic resins should reduce the amount of tanning materials now required to produce high-quality leather. The success of the resin treatments, coupled with the knowledge gained in their development, suggested the possibility of a similar leather treatment using rubber. Further research is being directed toward this end by Bureau scientists.

During World War II the military and civilian requirements for shoes were so great that the tanning industry experienced difficulty in expanding operations sufficiently to meet the increased demand. Of chief concern were the acute shortages of hides and tannins (quebracho and other vegetable tannins). To alleviate the situation, the Bureau investigated several oil and wax treatments, which were adopted by the Armed Forces to increase the wear-resistance of sole leather. During these investigations it became evident that treatment with synthetic resins might further im-

[8] For further technical details, see Treatment of leather with synthetic resins, by Rene Oehler and Timothy J. Kilduff, J. Research NBS **42,** 63 (1949) RP1951.

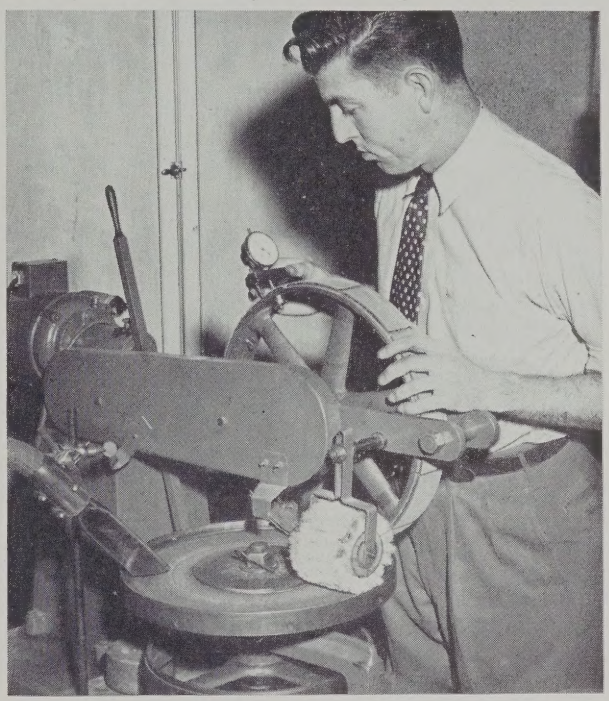
prove the wear of soles as well as make them and the upper leather more water resistant.

As a result of the war stimulus, three laboratory methods were developed for treating leather with resins. The first method of treatment may be accomplished by immersing the leather specimens in monomer and subsequently polymerizing *in situ;* the second method consists in immersing leather in polymer solutions, which may or may not be elastomers; while the third involves immersion in a partially polymerized liquid resin that is further polymerized in the leather itself. In connection with the second method, guttapercha, Castilloa, and Hevea natural rubbers, as well as synthetic elastomers and various acrylate solution-polymers were tried. The third method of impregnation was developed in cooperation with the Thiokol Corporation, using Thiokol LP–2.

Abrasion resistance as determined with the NBS abrasion machine—an indication of the wear to be expected of sole leather—is improved approximately 75 percent for vegetable-tanned crust leather impregnated with *n*-butyl methacrylate monomer, followed by polymerization *in situ.* The abrasive resistance of the untreated crust leather is approximately the same as that of sole leather. Treatment of vegetable-tanned crust leather with solutions of Castilloa rubber improves abrasion resistance about 50 percent, whereas treatment with Thiokol LP-2 improves resistance about 30 percent. However, treatment of vegetable-tanned crust leather with polybutyl methacrylate solution-polymer showed no improvement in abrasion resistance.

Results of half-hour static water absorption tests reveal a reduction of one-tenth to one-third the amount of water absorbed by untreated leather, depending upon the kind of leather and treatment. Water-vapor permeability of treated shoe upper leather is higher than similar leather containing 20 percent of grease.

Preliminary research with rubber solutions has shown that, by proper choice of processing methods, as much as 20 percent of rubber can be deposited within unfinished vegetable-tanned leather. The process may be satisfactorily applied to several different types of leather. Dynamic, or wet-flex, water absorption and water transmission of sole leather as well as abrasion resistance are all improved about 50 percent by rubber treatments. Solutions of natural rubbers having 40 percent or more of rubber are prepared from cold milled rubbers and conventional solvents. The impregnated rubber may be vulcanized in place by the use of an ultra accelerator of the dithio-carbamate type. Service tests on shoe soles and pilot plant processing runs are planned as the next step in the investigation.



Twelve specimens of sole leather are tested simultaneously with the NBS abrasion machine. Abrasion loss, or loss in thickness, is an important factor affecting the serviceability of the leather. Comparative values of the expected wear may readily be estimated with this machine for untreated and resin-impregnated leathers.

Corrosion Tests of Iron and Steel Pipes

To provide comprehensive data on the relative corrosion resistance of commercial pipe materials to cold flowing water, continuous-flow laboratory tests [9] extending over a 10-year period have been made on a number of these materials by G. A. Ellinger, L. J. Waldron, and S. B. Marzolf of the Bureau's Metallurgy Division. Since replacement of corroded water pipe—often involving the rebuilding of walls and floors through which the pipes run—is almost always expensive, the results of this investigation have provided the building and plumbing industries with useful information. Studies of the data indicate that while there were significant differences in the corrosion of some of the materials, the more expensive pipes offer no appreciable advantage in this respect over the usual cast-iron water pipe.

In the Bureau's investigation, tap water of known analysis was circulated at constant velocity through a system of eight vertical columns, each made up of 14 specimens of pipe lengths. The specimens consisted of two types of cast iron, three of wrought iron, two of ingot iron, and three of open-hearth steel. Individual specimens were removed and replaced with new ones of the same materials at the end of specified periods ranging in length up to 10 years. Corrosion of the exposed pipe, as indicated by loss of weight and depth of pits, was then evaluated in relation to duration of exposure.

To prepare the specimens, 5½-inch lengths were cut

[9] For further technical details, see Laboratory corrosion tests of iron and steel pipes, by G. A. Ellinger, L. J. Waldron, and S. B. Marzolf, Paper Trade Journal **127** (No. 10), 27 (1948); also 1948 Preprint No. 21, American Society for Testing Materials.

Identification symbol and composition of materials

Identification symbol	Material	Composition, percent									
		C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Graphite
A	Wrought iron—aston process	0.02	0.04	0.092	0.025	0.18	0.03	.....	.....	.....	.....
B	Wrought iron—hand puddled	.02	.06	.16	.012	.12	.04	.....	.....	.....	.....
C	Cast iron—centrifugal cast	3.61	.64	.34	.088	2.46	.37	.....	0.33	.....	2.96
D	Cast iron—sand cast	3.57	.54	.57	.071	2.26	.15	.....	.09	.....	2.97
E	Open hearth steel	.18	.43	.010	.017	.18	.05	.....	.....	.....	.....
F	Copper bearing steel	.11	.42	.007	.022	.19	.29	.....	.....	.....	.....
G	Ingot iron	.02	.03	.005	.026	.01	.05	.....	.....	.....	.....
H	Cu-Mo ingot iron	.03	.14	.008	.012	.01	.45	.....	.....	0.07	.....
I	Cu-Cr-P-Si steel	.08	.21	.16	.016	.80	.39	.....	1.10	.....	.....
J	Nickel-bearing wrought iron	.02	.05	.087	.012	.10	.08	1.72	.....	.....	.....

from the pipes, and the ends were machined smooth and parallel. In order to remove all surface dirt, grease, and mill scale, the test sections were first washed thoroughly in strong alkali or soap solution. This was followed by treatment with 10-percent sulfuric acid and an additional washing in clean soap solution. Corrosion of exterior surfaces of the pipes was prevented during the tests by coating with asphalt varnish.

The equipment was designed to permit the continuous uniform exposure of the inner surfaces of all of the specimens to water of known composition and constant velocity. Except for the metal specimens, the water within the apparatus came in contact only with rubber, glass, and stainless steel. Metallic contact and subsequent galvanic action between adjacent specimens was prevented by the use of separating rings of hard rubber. The specimens were fitted securely into recesses machined in the separators, and the entire column was made watertight by means of three equally spaced external tie rods. Care was taken to secure junctions as smooth as possible, since any projection, crevice, or irregularity would interfere with the normal flow of the water and create artificial turbulence and eddies. Turbulence of the water entering the apparatus was prevented by the insertion of a number of parallel glass rods in the top of each column. The columns were supported in a vertical position and maintained in a watertight condition by the tie rods, guide and supporting sleeves, and stainless steel holders. The capacity of the entire apparatus, including the top and bottom tanks and all columns and overflow pipes, was about 70 gallons.

After removal from the test columns, the specimens were dipped in trichlorethylene to dissolve the varnish. Corrosion products were removed by washing and treatment with 10-percent sulfuric acid and dilute caustic soda. The specimens were weighed, and the corrosion losses were calculated in grams per unit of interior surface area. The specimens were then sawed longitudinally, and the depths of the pits on the corroded surfaces were measured.

It was found that corrosion of the interior surfaces of the pipes started with the formation of small localized mounds of rust, the number and size of which increased with time. The rust that formed during the first year or two was lightly adherent and was easily removed. However, as corrosion continued, the rust coating became denser, more tightly adherent, and more difficult to remove as most of the mounds developed into a tubercular form of rust. Many uncorroded areas were found on the surfaces of the specimens during the first several years of testing, but few were found on specimens exposed for more than 5 years. The pH of the water was such that small amounts of calcium carbonate were deposited with the rust, probably increasing the protective effects of the rust coating.

Although the results show a certain amount of scatter among the individual specimens, a rather definite trend was established early in the test and continued throughout its life. Materials that showed the highest loss of weight or depth of pits in the early stages generally maintained this trend throughout. With respect to loss of weight, the test materials fall into three groups. Materials B, E, F, G, H, and J had the lowest corrosion losses; somewhat higher losses were experienced by materials A, D, and C; material I had the highest losses.

The average depth of pits at the end of 7 years showed considerably more difference than the average loss of weight. Again the materials tested could be divided into three groups. Materials C, J, and H had the shallowest pits; intermediate pit depths occurred in materials A, E, G, and F; and materials D, B, and I had the deepest pits.

The shallowest pits occurred in the centrifugally cast iron, whereas the sand-cast iron had pits approximately twice as deep. Since the loss of weight was about the same for both materials, these results indicate that the corrosion of the centrifugally cast iron was general, with little localized deep pitting, whereas that of the sand-cast iron was largely by deep pitting. The condition of the casting skin of these materials was probably largely responsible for the difference in corrosion characteristics.

Failure of any piping material in actual service usually results from perforation of the wall by pitting, with resultant leakage. It might be expected that the depth of the deepest pit would control the time required

In apparatus used for studies of the corrosion resistance of commercial pipe materials, tap water of known analysis was circulated at constant velocity through a system of eight vertical columns, each made up of 14 specimens of pipe lengths. Corrosion was evaluated in terms of loss of weight and average depth of pitting.

for a pipe to wear completely through, but no evidence was found to indicate that the deepest pit at any intermediate stage of the test would be necessarily the first to perforate. On the other hand, some evidence was obtained that pitting might be inhibited at times by the deposition of chemical compounds or by the formation of corrosion products in the bottoms of the pits, thus preventing or retarding subsequent attacks. With the exception of the two cast irons, which had greater wall thicknesses than the wrought materials, the average depths of pits after 7 years represented penetrations of from 20 to 40 percent of the wall thickness, whereas after 10 years the penetrations were from 25 to 26 percent. If the depths of the deepest pits are used as criteria, the penetration of corrosion into the various materials, other than the cast irons, ranged between 30 and 70 percent after 7 years of testing. In those tested for 10 years, the penetration ranged from 36 to 52 percent.

Comparison of the average depths of pitting obtained in these tests with those obtained in other tests still under way at the Bureau on actual service lines indicates that approximately 50 percent greater corrosion occurred in the laboratory tests than in the service lines. This is probably due to the continuous flow of the water in the laboratory tests as compared with intermittent flow in the service lines. In the laboratory the corrosion products would tend to be removed more rapidly than in the service lines; thus in the latter the accumulation of corrosion products might be expected to retard the corrosion process to some extent.

The results of the tests indicated that there was no great difference in the rates of corrosion of most of the wrought materials when measured either by loss of weight or by depth of pitting. A low-alloy steel had the highest corrosion rate, whereas a copper-molybdenum ingot iron and a nickel-bearing wrought iron had the lowest rates. Other low-alloy materials such as wrought irons, ingot iron, and ordinary medium carbon steel pipes corroded at intermediate rates. A rough estimate of the minimum life of these bare materials when subjected to continuous flow of Washington, D. C., water would be about 15 years on the basis of this work.

Standard Frequency Broadcasts From Hawaii

A new experimental radio station on the island of Maui, Territory of Hawaii, is now broadcasting continuous time and frequency standards under the call letters WWVH on 5, 10, and 15 megacycles. Station WWVH, operated by the National Bureau of Standards, provides the Pacific area with four useful technical services: Standard radio frequencies, time announcements, standard time intervals, and standard musical pitch. Omnidirectional antennas radiate approximately 400 watts of power on each carrier frequency.

The broadcast services of WWVH are essentially the same as those of station WWV, operated by the Bureau at Beltsville, Md., which transmits on frequencies of 2.5, 5, 10, 15, 20, 25, 30, and 35 Mc.[10] It is expected that station WWVH may be usefully received at many locations not served by station WWV, and that simultaneous reception of WWV and WWVH in some localities will not interfere with ordinary use of the standard frequencies and time signals.

Reception reports and experimental data on the operation of WWVH will further the study of proposals for increasing the service area of standard-frequency broadcasts. An international group sponsored by the International Telecommunications Union is now actively considering this problem. The ultimate aim is to provide continuous world-wide coverage by means of several suitably located stations, all operating on the same frequencies. This must be achieved without mutual interference or degradation of the widely used services from WWV and without limiting the usefulness of the standards by setting up a complicated schedule of operation for the various stations.

[10] Details of the WWV technical radio broadcast services are described in Letter Circular LC886, available upon request to the National Bureau of Standards, Washington 25, D. C.

During the continuous operation of WWVH on 5, 10, and 15 Mc, accurate time signals in the form of audio-frequency pulses (0.005-second duration) are transmitted on each carrier frequency at intervals of precisely 1 second; on the 59th second of each minute the pulse is omitted. Standard musical pitch is provided by modulating each carrier at a standard audio frequency of 440 cycles per second (A above middle C). The audio frequency, starting precisely at the beginning of each hour, is broadcast for 4 minutes and interrupted for 1 minute; this sequence is repeated throughout the hour. Greenwich Mean Time is given in International Morse Code every 5 minutes; time announcements refer to the time when the audio tone returns. The station call letters WWVH follow each time announcement.

The entire broadcast (modulation and carrier) is interrupted for periods of approximately 4 minutes immediately after each hour and half hour, and for periods of approximately 30 minutes beginning at 0700 and 1900 GMT. These interruptions are made to permit operation of automatic ionospheric sounding equipment at the Hawaiian field station and to compare the local standards at WWVH with broadcasts by station WWV.

The radio and audio frequencies and time intervals of 1 minute or longer broadcast by WWVH are accurate to one part in fifty million or better. Time signals are precisely adjusted with U. S. Naval Observatory time so that they accurately mark the hours and shorter intervals. Seconds pulses from WWVH are synchronized to within 0.001 second with those sent out by WWV.

The Bureau welcomes reports on reception of station WWVH, particularly with reference to (1) areas now served by WWVH but not served by WWV, (2) interference experienced by users of station WWV, (3) beat frequency observed during simultaneous reception of WWV and WWVH, (4) uncertainties experienced in adjusting precision local standards with reference to frequencies or seconds pulses during simultaneous reception, (5) quality of tone modulation during simultaneous reception, (6) special applications requiring simultaneous reception from two or more standard frequency stations, (7) methods of operation to give more useful service. All correspondence should be addressed to the Central Radio Propagation Laboratory, National Bureau of Standards, Washington 25, D. C.

NBS Publications

Periodicals [11]

Journal of Research of the National Bureau of Standards, volume **43,** number 2, February 1949. (RP1953 to RP1961, inclusive.)

Technical News Bulletin, volume **33,** number 2, February 1949. 10 cents.

CRPL–D54. Basic Radio Propagation Predictions for May 1949. Three months in advance. Issued February 1949. 10 cents.

Nonperiodical

Research Papers [11 12]

RP1946. Response functions for types of vision according to the Muller theory. Deane B. Judd. 10 cents.

RP1947. Rate of shrinkage of tendon collagen: Heat, entropy, and free energy of activation of the shrinkage of untreated tendon; Effect of acid, salt, pickle, and tannage on the activation of tendon collagen. Charles E. Weir. 10 cents.

RP1948. Kinetic study of the reaction of carbon adsorbents with oxygen. William V. Loebenstein, Leland F. Gleysteen, and Victor R. Deitz. 10 cents.

RP1949. Weather resistance of porcelain enamels exposed for seven years. William N. Harrison and Dwight G. Moore. 10 cents.

RP1950. On the precision of a certain procedure of numerical integration. Harry D. Huskey and Douglas R. Hartree. 10 cents.

RP1951. Treatment of leather with synthetic resins. Rene Oehler and Timothy J. Kilduff. 10 cents.

RP1952. Noise spectrum of a diode with a retarding field. Jacob J. Freeman. 10 cents.

Commercial Standards [11]

CS105–48. Mineral-wool insulation for low temperatures. (Second edition. Supersedes CS105–43.) 10 cents.

CS148–48. Men's circular flat- and rib-knit rayon underwear. 10 cents.

Miscellaneous [11]

M191. Charts of compressibility factors and charts showing quantities delivered by commercial cylinders for hydrogen, nitrogen, and oxygen. Harold J. Hoge, Cyril H. Meyers, and Robert E. McCoskey. 25 cents.

Letter Circulars [13]

LC931. List of commercial standards, revised to January 1, 1949. (Supersedes LC911.)

LC932. Simplified practice recommendations. Alphabetical list revised to January 1, 1949. (Supersedes LC913.)

LC933. Definition of pH, and standards for pH measurements.

LC934. Light-sensitive paper no. 1554: Directions for use in testing textiles for colorfastness to light.

Articles by Bureau Staff Members in Outside Publications [14]

Burned shale and expanded slag concretes with and without air-entraining admixture. P. H. Petersen. J. Am. Concrete Inst. (7400 Second Boulevard, Detroit 2, Mich.) **20,** 165 (1948).

Transition from international to absolute electrical units as it affects the physical chemist. George W. Vinal. J. Wash. Acad. Sci. (c/o Harold A. Rehder, U. S. National Museum, Washington 25, D. C.) **38,** 265 (1948).

Remarks on measurement of electromotive force of a microphone. Richard K. Cook. J. Acoustical Soc. of America (57 East Fifty-fifth Street, New York 22, N. Y.) **20,** 874 (1948).

Thermal voltages of a quartz crystal. Richard K. Cook, Martin Greenspan, and Pearl G. Weissler. The Physical Review (57 East Fifty-fifth Street, New York 22, N. Y.) **74,** 1714 (1948).

[11] Send orders for publications under this heading only to the Superintendent of Documents, Government Printing Office, Washington 25, D. C. Annual subscription rates: Journal of Research, $4.50 (foreign $5.50); Technical News Bulletin $1.00 (foreign $1.35); Basic Radio Propagation Predictions, $1.00 (foreign $1.25). Single copy prices of publications are indicated in the lists.

[12] Reprints from January Journal of Research.

[13] Letter Circulars are prepared to answer specific inquiries addressed to the National Bureau of Standards, and are sent only on request to persons having a definite need for the information. The Bureau cannot supply lists or complete sets of Letter Circulars or send copies automatically as issued.

[14] These publications are not available from the Government. Requests should be sent direct to the publishers.

U. S. GOVERNMENT PRINTING OFFICE: 1949